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THE McCOWAN ROAD RIGHT-OF-WAY STUDY FINAL REPORT: STUMP SPROUTING AND SUCKERING, AND THE DEVELOPMENT OF WOODY VEGETATION IN THE SIX YEARS FOLLOWING CLEARCUTTING

Report 91-105-K

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ABSTRACT

A study was initiated in 1984 to describe the growth of trees following clearing of a wooded area for a transmission right-of-way. This report discusses the changes in woody species composition during the first 6 years of the study, concentrating on the relative importance of root suckers, stump sprouts and tree seedlings to the formation of the tree canopy. The survival and growth rates of sprouts and suckers associated with selected stumps of sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), trembling aspen (*Populus tremuloides*) and black cherry (*Prunus serotina*) are also reported.

job	file	date	report no.
34-552-090	834.1	May 31, 1991	91-105-K

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EXECUTIVE SUMMARY

THE McCOWAN ROAD RIGHT-OF-WAY STUDY FINAL REPORT: STUMP SPROUTING AND SUCKERING, AND THE DEVELOPMENT OF WOODY VEGETATION IN THE SIX YEARS FOLLOWING CLEARCUTTING

The vegetation management techniques used on Ontario Hydro rights-of-way must be capable of controlling tall-growing trees. The development of an integrated control policy is complicated by the fact that these stems originate from sources with contrasting growth characteristics. Stump sprouts and root suckers produced by ineffectively removed trees have higher survival and growth rates than stems developing from seeds. Seedlings however, may be more numerous. It is important to determine the role of these sources in generating problematic stems on the right-of-way, so that construction, maintenance and research efforts can concentrate on the major problems.

A woodlot dominated by sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), trembling aspen (*Populus tremuloides*) and black cherry (*Prunus serotina*) was clearcut in the fall of 1984. Vegetation surveys were conducted in the spring of the first, and in the fall of the second, fourth and sixth years post-clearing to document the change in woody species composition and investigate the source of the incompatible stems. The post-clearing canopy, dominated by seedlings of black cherry and white ash, had a density of 4.53 stems·m^{-2}. Rapid proliferation of trembling aspen suckers, and growth of choke cherry (*Prunus virginiana*) and raspberry (*Rubus idaeus*) seedlings increased the density to 31.81 stems·m^{-2} by the end of the second year. By the sixth year, the trembling aspen and choke cherry had declined, while white ash had increased. The overall density has declined to 22.09 stems·m^{-2}.

The densities of seedlings and sprouts were similar in years 2, 4 and 6. However, the sprouts have always been the tallest stems, and thus represent the major control problem. By the sixth year, the majority of the seedlings were under 1 m and none were taller than 5 m. In contrast, 20% of the sprouts were at least 5 m tall, and some were approaching 8 m.

A second phase of this study was undertaken to investigate the growth and survival characteristics of sprouts and suckers originating from the stumps of 324 trees which were removed from the site in 1984. The total number of stems associated with the stumps have declined, and are converging to a range of 5 to 7 stems·stump^{-1}, irrespective of species. Thus the most prolific sprouters, black cherry and white ash, exhibited the highest stem mortality, while the poorest sprouter (sugar maple) experienced better survival

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during the study. The height growth of the sprouts was greatest in the year following cutting and rates have declined ever since. Black cherry and trembling aspen had the highest growth rates, and white ash, the lowest. In some species, sprout growth was correlated to parent tree age, height or diameter. However, the ability to predict growth from these parameters is very poor.

It is apparent from this study that the ground cover remaining after the clearing of a new right-of-way will not inhibit tree establishment or growth. Based on the height of the upper quartile stem, reclearing will be required in the first year for areas dominated by black cherry, the second year in aspen sites and the third year for sugar maple or white ash dominated areas.

Several selective herbicide treatments are normally required to gain control over sprouts. If chemicals are not available for use, more extensive site preparation, possibly involving grubbing of the stumps, soil scarification and planting of an appropriate cover crop, may be necessary to rapidly establish control over the trees.

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To: Dr. D. Mills
Director of Research

THE McCOWAN ROAD RIGHT-OF-WAY STUDY FINAL REPORT: STUMP SPROUTING AND SUCKERING, AND THE DEVELOPMENT OF WOODY VEGETATION IN THE SIX YEARS FOLLOWING CLEARCUTTING

1. INTRODUCTION

The first stage in the construction of a utility right-of-way through a forested region involves the removal of all tall growing woody vegetation. Unfortunately, the areas are quickly revegetated with species similar to the previous forest communities (Jensen 1943, Thibodeau and Nickerson 1986, Albert and Barnes 1987). Sprouts quickly develop from the stumps of the cut trees, while suckers invade from the root system of trees in the neighbouring areas and from the stumps on the right-of-way. The advance regeneration (seedlings present prior to clearing) is released by the removal of the canopy. Stems will also develop from seed sources in the area.

This large diversity in the source of the incompatible stems makes it difficult to develop the integrated management policy necessary to maintain the right-of-way with low growing vegetation compatible with its use by the utility. Vegetative reproduction from sprouts and suckers produces a rapid, dense growth which causes immediate problems. Information is required on the growth rates and survivorship of these stems to schedule the maintenance treatments such that the most effective results are achieved.

Stems originating from seed sources may be more numerous and widespread, but have lower initial growth rates than vegetative stems. There is the potential for a highly competitive ground vegetation to interfere with the establishment and growth of these seedlings, thus reducing this ever present problem. Some shrub communities have been shown to resist tree invasion for several decades (Pound and Egler 1953, Bramble and Byrnes 1976, Niering *et al.* 1986), while various grasses and forbs may also provide a high degree of interference (Horsley 1977a, b, Suffling 1979, Brown 1989). Direct planting of resistant communities on the right-of-way is possible, however studies on the importance of seedling growth relative to that of the sprouts and suckers are necessary to indicate if this approach is desirable.

A long term study was initiated in a woodlot near McCowan Road in Markham to assess the natural pattern of vegetative development on a newly cleared area. The objectives of the study (Kirby 1984) were to

1. Determine the relative proportion of incompatible stems originating from seed and cut stumps.
2. Determine the growth rates of stems originating from seed and cut stumps.
3. Determine the safe sites for seed establishment and identify nurse crops.
4. Determine the origin of the tree seed which germinates on the right-of-way (seed bank or seed rain).

This report summarizes the development of the woody vegetation at the site during the six growing seasons following clearing. It discusses stump mortality, sprout survival and the growth of sprouts and suckers during this time and investigates the feasibility of predicting those responses from the preclearing conditions of the right-of-way. In addition, a study into the relative importance of seedlings, sprouts and suckers in the development of an incompatible tree canopy is also included. Previous investigations on the shrub and tree development at this site were in the spring of 1985 (Arron 1985) and September, 1986 and 1988 (Brown 1987 a,b,c, 1989).

2. METHODS

The McCowan Road site consists of a 0.3 hectare (70 x 42 m) section of woodlot in Markham, adjacent to an established right-of-way (north of towers 58 and 59 of the 500 kV Cherrywood to Clairville transmission line).

To enable a long-term investigation of the sprouting dynamics, 348 trees (with diameters greater than 7.0 cm at a height of 0.3 m) were marked with aluminum tags. The diameter, height and age of each tree were recorded prior to cutting (Kirby 1984).

This site was selectively cleared of all incompatible woody species in the fall of 1984. The trees removed from the site included 107 sugar maple (*Acer saccharum*), 97 trembling aspen (*Populus tremuloides*), 94 white ash (*Fraxinus americana*) and 19 black cherry (*Prunus serotina*).

Vegetative reproduction in the aspen is primarily by root suckers, while sprouting from the stump is the major source of stems in the other species. (See Arron (1983) for a summary of the factors which affect sprouting and suckering.) The growth of sprouts and suckers from these stumps for the fall of 1985, 1986, 1987 and 1988 has been previously reported in Arron (1986) and Brown (1987a, b, 1989). The growth in the fifth and sixth years of the study was determined in November 1989 and September, 1990. Each stump was located and the number of stems (sprouts and suckers) and the height of the dominant (tallest) stem associated with each stump were recorded.

An investigation was also undertaken to determine the extent and source of the woody growth at the site. The area was sampled in September, 1990 with a grid of 79 1 x 1 m quadrats located at 5 m intervals. Within each quadrat, the number of stems of each woody species was determined. All stems of the incompatible tree species were further separated into seed or vegetative (sprout and sucker) classes and the height of the tallest stem in each class was measured. Data proir to 1989 has been previous reported in Arron (1985) and Brown (1987c, 1989).

3. RESULTS

3.1 The changes in woody vegetation composition

The removal of the tree canopy in 1984 resulted in the immediate invasion of woody species at McCowan Road. Stem densities rose from 4.53 stems·m^{-2} in the spring of 1985 to 31.81 stems·m^{-2} by the fall of 1986 (Table 1). This proliferation did not continue, and the total density has now declined to 22.09 stems·m^{-2}. The changes between 1985 and 1986 were primarily attributed to increases in the understorey shrubs (choke cherry, raspberry) and suckering from trembling aspen roots (Figure 1). The choke cherry and aspen have declined dramatically between 1986 and 1990. White ash has now become the most

Table 1

The density of woody species at McCowan Road.

Species	Common name	Density (stems·m^{-2})			
		1985	1986	1988	1990
Acer negundo	Manitoba maple		0.01		
Acer saccharum	sugar maple	0.31	3.69	4.99	1.76
Acer spicatum	mountain maple		0.09		
Amelanchier sp.	service berry				0.03
Betula papyrifera	paper birch		0.04		
Carya cordiformis	bitternut hickory		0.01		
Cornus sp.	dogwood	0.02	1.69	0.82	0.60
Crataegus sp.	hawthorn	0.04	0.03	0.28	0.09
Fagus grandifolia	American beech		0.85		
Fraxinus americana	white ash	1.16	2.92	5.11	6.30
Juglans cinera	butternut		0.01	0.07	0.09
Lonicera sp.	honeysuckle		0.01		0.05
Malus sp.	apple		0.07		
Ostrya virginiana	ironwood	0.01	0.01		0.26
Populus tremuloides	trembling aspen	0.56	5.16	2.41	2.08
Physocarpus opulifolius	ninebark				0.17
Prunus virginiana	choke cherry		8.07	9.12	4.26
Prunus pensylvanica	pin cherry		0.24	0.04	0.36
Prunus serotina	black cherry	2.40	1.01	0.04	0.42
Rhamnus cathartica	common buckthorn		0.10	0.04	0.99
Ribes sp.	gooseberry		.08	0.23	0.28
Rubus allegheniensis	blackberry		0.28		0.09
Rubus idaeus	raspberry	0.03	5.10	4.55	3.37
Rubus occidentalis	black raspberry		1.07	0.41	
Thuja occidentalis	white cedar			0.01	0.03
Tilia americana	basswood	0.01	1.06	0.04	
Tsuga canadensis	hemlock			0.01	0.03
Sorbus americana	mountain ash				0.01
Ulmus americana	white elm			0.08	0.26
Viburnum trilobum	high bush cranberry		0.08	0.12	0.14
Viburnum lentago	nannyberry		0.13	0.36	0.42
all stems		4.53	31.81	28.73	22.09

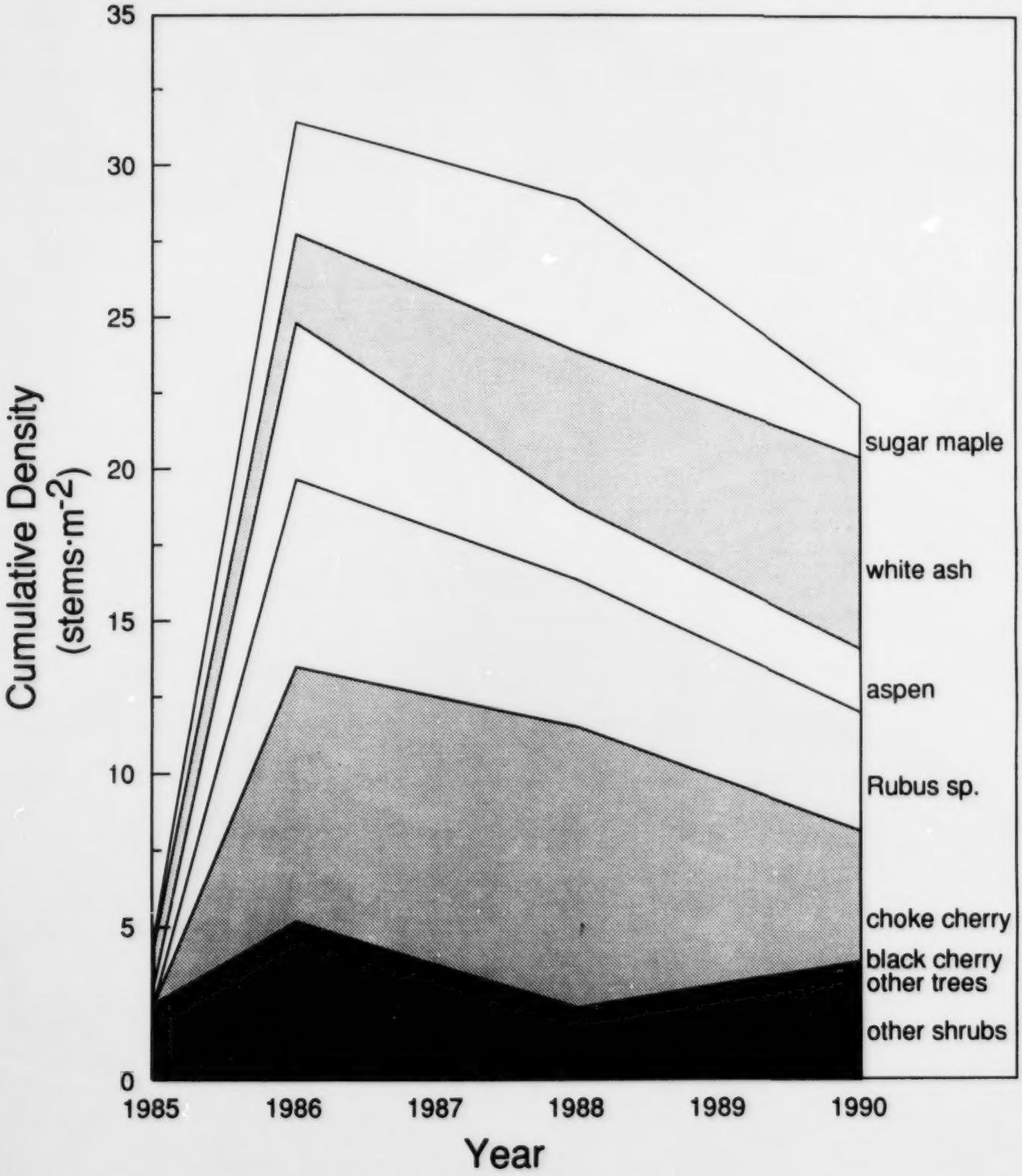

Figure 1: The change in woody stem density

numerous species (6.30 stems·m^{-2}), and along with choke cherry, raspberry and other shrubs, comprise 87% of the total woody stem density.

The relative contributions of seedlings (and saplings) and sprouts (and suckers) to the tree density is shown in Figure 2. The data indicates a shift in the numerical dominance from seedlings to an even mixture of seedlings and sprouts. The site was dominated by seedlings of ash and cherry in the spring of 1985 (Figure 2, and Arron 1985). Rapid proliferation of aspen suckers resulted in a canopy where 60% of the stems were of vegetative origin by the 1986 survey. By 1988, an increase in the density of white ash and sugar maple seedlings and a decline in aspen suckers reversed the total stem composition to one in which 65% originated from seeds. Many of the maple seedlings have died between 1988 and 1990, shifting the balance back to a mixture dominated by vegetative growth (55%).

Although the densities of seedlings and sprouts are similar in years 2, 4 and 6, the sprouts have always represented the largest stems (Figure 3). By 1990, the majority of the seedlings were under 1 m and none were taller than 5 m. In contrast, 25% of the sprouts were at least 5 m tall, and some were approaching 8 m.

3.2 Stem development on permanently located stumps

With the exception of white ash, few changes in the number of stumps that produced sprouts or suckers could be observed beyond 1987 (Figure 4). It appears that significant stump mortality was restricted to the first and second years following cutting, and was important only for sugar maple and white ash. Stump mortality in white ash continued to increase until at least 1989.

Stump mortality cannot be estimated with much certainty from the age, height or diameter of the parent tree. Table 2 lists the results of t-tests comparing these characteristics from sprouting and non-sprouting stumps in 1987. Only 2 significant differences were found. The suckering trembling aspen trees were younger than those which did not sucker, and fewer large diameter sugar maple stumps sprouted.

The total number of sprouts and suckers associated with the stumps has also declined. The largest reduction occurred with the most prolific sprouters, black cherry and white ash (Figure 5). Trembling aspen also showed a steady decline, while sugar maple has undergone no significant change between 1985 and 1990. The mean number of stems on each surviving stump is converging to a range of 5 to 7 stems·stump^{-1} for all species (Figure 5).

The growth of the tallest sprout on each surviving stump follows a curvilinear pattern. Growth is highest in the first year following cutting, and rates have been gradually declining since then (Figure 6). Ash had the slowest growth during this study, while black cherry and trembling aspen had the highest. The cherry have undergone a slight dieback in 1990. Many of the surviving cherry stems had sparse canopies with discoloured leaves.

Table 3 is a summary of the rank correlations between sprout growth (height and number in the surviving stumps in 1985 and 1990) and some characteristics of the parent tree (height, age and diameter). The only variable with a significant correlation ($p > 0.05$) with sprout number in 1985 was tree height in sugar maple. Sprout number in 1990 correlated with the 1985 sprout number in white ash, trembling aspen and sugar maple. The height of the tallest sprout on each stump in 1985 was correlated with tree height and the 1985 sprout number in trembling aspen and sugar maple, and with stump diameter in the maple. The sprout height in 1990 was correlated to white ash tree age, sugar maple diameter and the 1985 sprout height in white ash, trembling aspen and sugar maple. Sprouting in black cherry was not correlated with any of the variables.

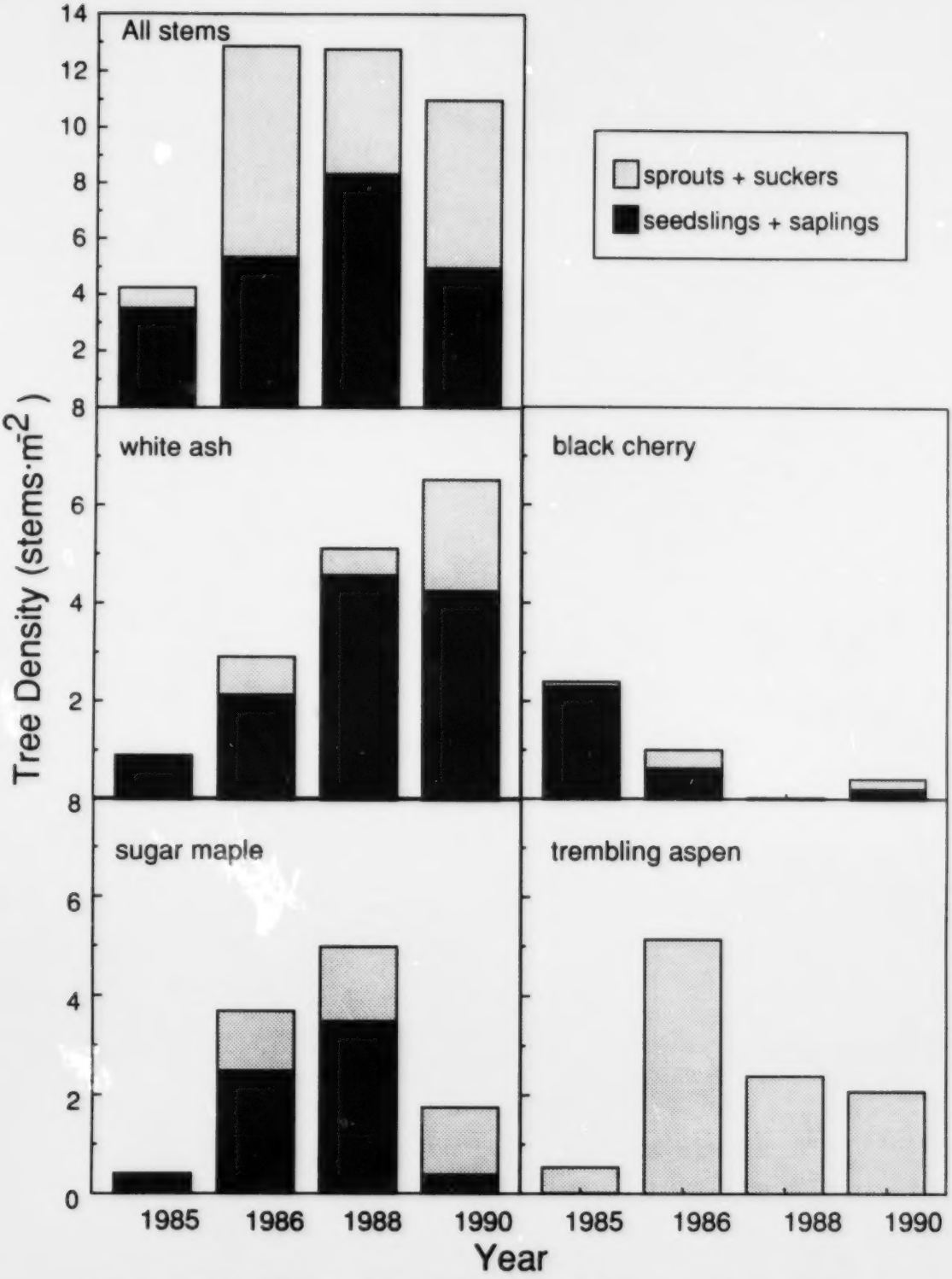

Figure 2: The relative proportions of trees from seed or vegetative origins

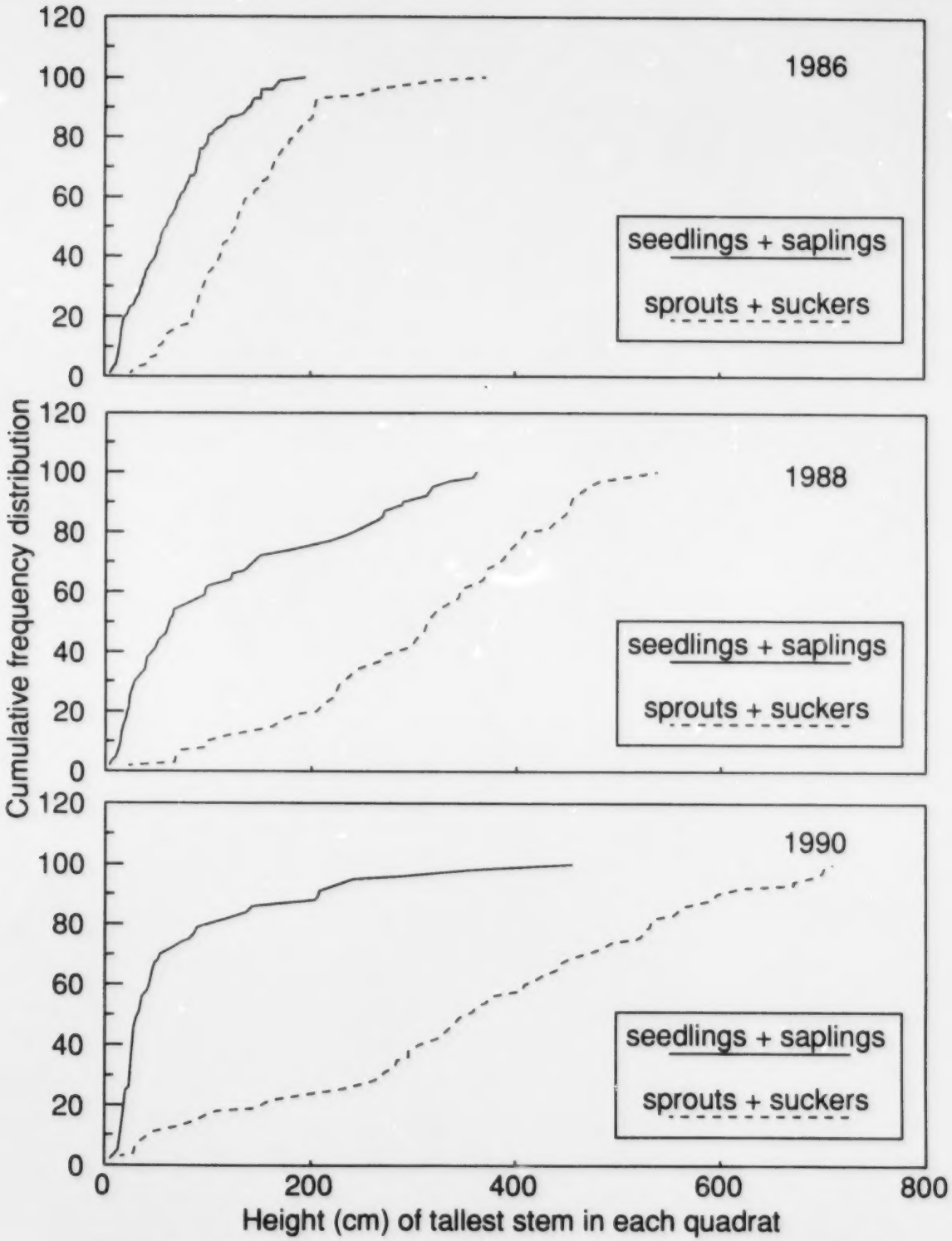

Figure 3: The height distributions of the tree seedlings and sprouts

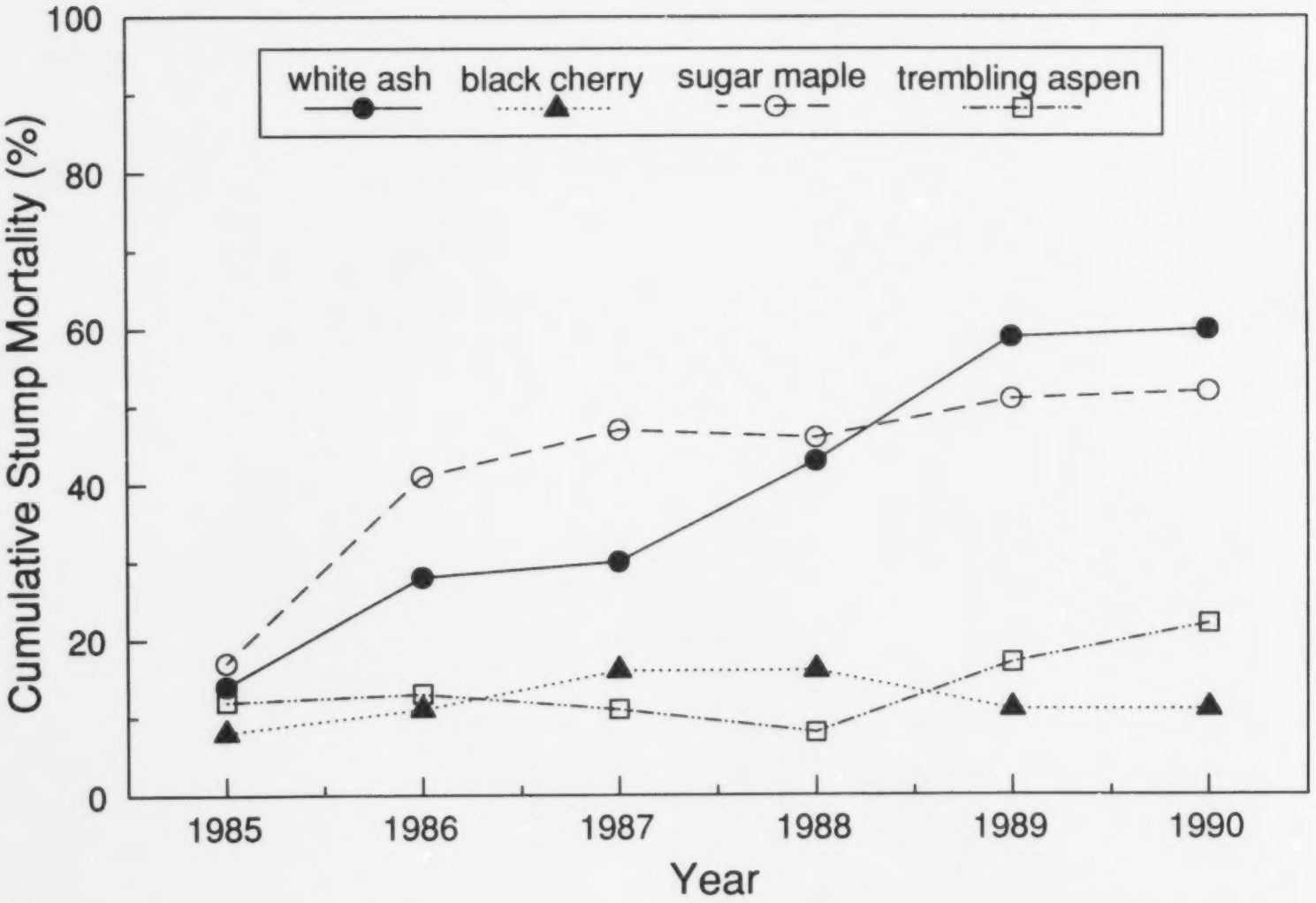

Figure 4: The mortality of tagged stumps at McCowan Road during the first six years of the study

Table 2: The relationships between stump parameters and stump mortality in 1987. Results of a t-test comparing sprouting and nonsprouting stumps.

	t-test	*p* of no effect	comments
Tree age			
white ash	-0.9640	0.3376	
black cherry	-0.7801	0.4460	
trembling aspen	-2.7556	0.0070	fewer older stumps sprouted
sugar maple	-0.6457	0.5199	
Stump diameter			
white ash	-0.9970	0.3214	
black cherry	-0.2096	0.8364	
trembling aspen	-1.0068	0.3166	
sugar maple	-2.8612	0.0051	fewer larger stumps sprouted
Tree height			
white ash	-0.5746	0.5669	
black cherry	0.5987	0.5572	
trembling aspen	-0.0347	0.9723	
sugar maple	-1.7429	0.0843	

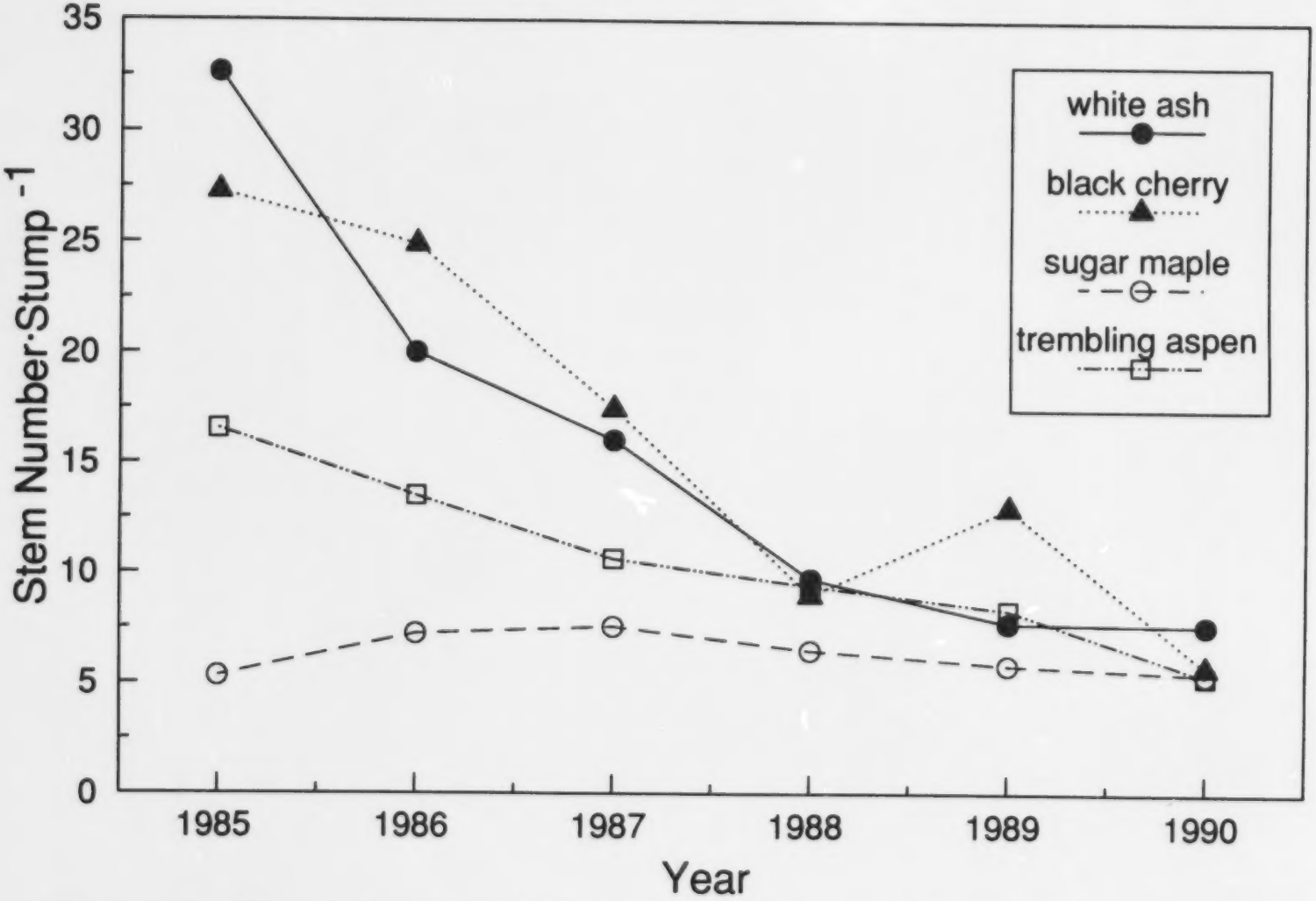

Figure 5: The mean number of sprouts or suckers on the surviving stumps at McCowan Road

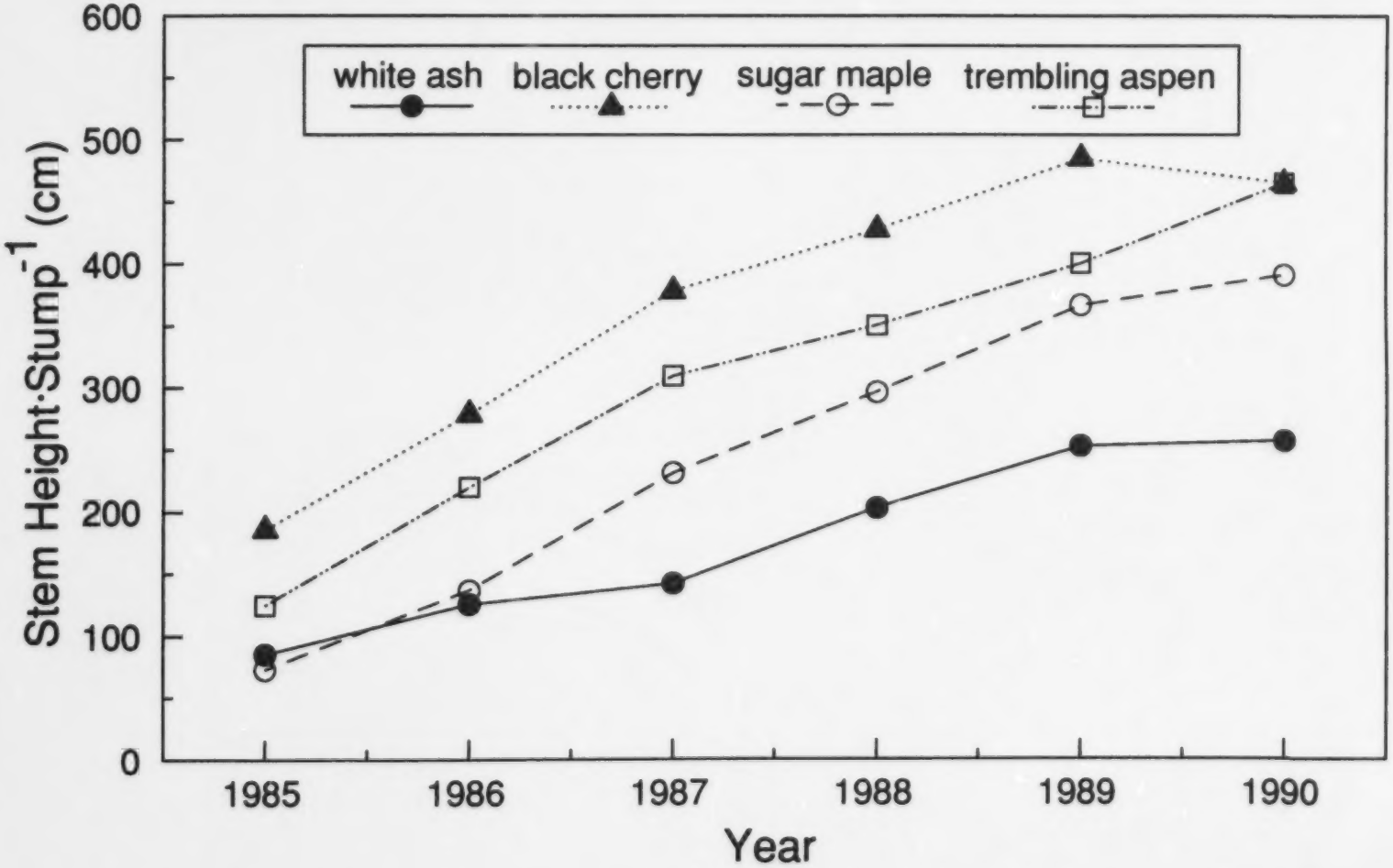

Figure 6: The mean height of the tallest sprout or sucker associated with the surviving stumps at McCowan Road

Table 3: The Spearman rank correlations (r_s) between sprout number, height and parent tree characteristics.

	Variable				
	tree age (yr)	tree diameter (cm)	tree height (m)	1985 sprout number	1985 sprout height (cm)
Sprout Number 1985					
white ash	-0.2792[1]	-0.0538	-0.1643		
black cherry	-0.0486	-0.0206	-0.4758		
trembling aspen	-0.0226	-0.0025	-0.0984		
sugar maple	-0.0729	-0.0952	-0.2847[2]		
Sprout Number 1990					
white ash	-0.2890[1]	0.2232	-0.0160	0.5989[3]	
black cherry	0.0502	-0.2128	-0.2441	0.3730	
trembling aspen	-0.0424	-0.0020	0.0442	0.5758[4]	
sugar maple	0.0784	0.2518[1]	-0.0636	0.3249[2]	
Sprout Height 1985					
white ash	0.0108	0.1347	0.2528[1]	-0.2477[1]	
black cherry	-0.1270	-0.4096	-0.1728	-0.0114	
trembling aspen	0.1832	-0.1791	-0.2579[2]	0.5277[4]	
sugar maple	-0.0577	-0.2757[2]	-0.2752[2]	0.5212[4]	
Sprout Height 1990					
white ash	0.3307[2]	0.0957	0.3142[1]	0.0656	0.6549[3]
black cherry	-0.2889	-0.0564	0.1036	-0.3105	0.4282
trembling aspen	-0.1352	-0.1352	0.0555	-0.0046	0.2885[2]
sugar maple	-0.0763	-0.3309[2]	-0.2706[1]	0.2754[1]	0.6699[4]

Probabilities for r_s: 1 $p > 0.10$ 2 $p > 0.05$ 3 $p > 0.01$ 4 $p > 0.001$

Although sprout growth in some species may be correlated to the size or age of the parent tree (Table 3), the ability to predict growth from these characteristics is poor. Table 4 gives the best fit equations for the significant correlations in Table 3. Parent tree height or age was a very poor predictor of sprout growth, explaining only 6 to 12% of its variability. Tree diameter was a better predictor, explaining 20% of the variability in 1990 spout height of sugar maple. Variation in the number of sprouts in 1985 can explain a large proportion (24 to 56%) of the variation in sprout height in 1985 and 1990. This does not indicate a direct effect of sprout number on height, as both are more likely affected by other variables which determine growth.

In the management of rights-of-way, a main concern will be the predicted growth of the taller stems rather that the mean growth of all stems. Ontario Hydro guidelines limit the use of foliar herbicide sprays to stems under 3 m tall. A treatment cycle involves two operations. A clearing operation, where all trees taller than the 3 m limit are cut, followed by the herbicide application. The spraying is usually done the year following the cutting, to allow those stumps which were cut to sprout and be treated with the herbicide. Thus the cutting crew will not only cut all trees above the height limit, but must also extrapolate the growth of the stems to cut those that will be taller that 3 m in the year the spraying is performed.

Using the mean estimates in Figure 6, sites dominated by black cherry will require cutting the second year following initial clearing, while aspen should be cut in the third year. Sugar maple dominated sites can be left for 4 years while an ash dominated site may not require cutting for at least 7 years. Cycle times based on mean growth predictions will result in half of the trees requiring cutting at that cycle. This is usually too many trees to allow for an optimum costs and use of manpower. Figure 7 describes the growth of the stems at the upper quartile. Thus only 25% of the stems will be taller than this value. In this situation, cutting will be required in the first year for areas dominated by black cherry, the second year in aspen sites and the third year for sugar maple or white ash dominated areas.

The actual cutoff limits for the stem height will differ from the 50 or 25% values used here. It should be dependent upon the increased cost of cutting stems relative to the cost of the pre-spray survey and the spraying operation itself.

4. DISCUSSION

It is quite apparent that the vegetation composition at the site is continually changing, although the rate of this change declines with time. The postclearing (spring 1985) woody vegetation, numerically dominated by black cherry and white ash was rapidly replaced by trembling aspen, choke cherry and raspberry by 1986-1988 (Figure 1). The aspen is now declining, while more sprouts of ash and maple are becoming established (Figure 2). The site is developing towards a woody species composition similar to the preclearing conditions. Other studies have indicated similar rapid transitions toward a forest structure (Thibodeau and Nickerson 1986, Albert and Barnes 1987). A beech-maple clear-cut in New Hampshire was initially invaded by raspberry, choke cherry and some herbaceous species (Jensen 1943). Choke cherry became the dominant species by year 5, with a density of 2.05 stems·m^{-2} (32% of the total tree density). This shrub was gradually overshaded by the trees, and was effectively removed from the understorey by year 25 (Marquis 1967). McCowan Road appears to be developing at a much faster rate than this (Figure 1, Table 1), as the choke cherry has started to die out by the 4th year (1988). The severe competition amongst the trees in this dense canopy is expected to result in a continuous decrease in stem numbers during the next few years.

Seedlings represent 80% of the initial stem densities, and 50% of the densities by 1990 (Figure 2). Two objectives of this study were to determine the safe sites and associated nurse species for seedling establishment and to determine the origin of the seeds (Kirby 1984). Safe sites and nurse species could not be identified from the data collected in this study. Seed bank estimates obtained from this site in the

Table 4: The ability to predict sprout growth from parent tree parameters.
Best fit equations for the significant correlations in Table 3.

Sprout Growth (y)	Estimator (x)	Function	% of variation explained	Signficance of regression
Sprout Number in 1985				
sugar maple	tree height	$y = -0.79x + 14.24$	12.02	0.0035
Sprout Number in 1990				
white ash	sprout number in 1985	$y = 2.17x^{0.41}$	40.64	0.0005
trembling aspen	sprout number in 1985	$y = 1.57x^{0.41}$	30.81	>0.0001
sugar maple	sprout number in 1985	$y = 3.21x^{0.24}$	10.61	0.0351
Sprout Height in 1985				
trembling aspen	tree height	$y = 490x^{-0.57}$	6.49	0.0346
trembling aspen	sprout number in 1985	$y = 62x^{0.26}$	30.15	>0.0001
sugar maple	stump diameter	$y = 285x^{-0.66}$	10.03	0.0080
sugar maple	tree height	$y = e^{-0.076x + 5.01}$	7.59	0.0219
sugar maple	sprout number in 1985	$y = 41x^{0.33}$	27.44	>0.0001
Sprout Height in 1990				
white ash	tree age	$y = 6.72x + 67$	6.32	0.1391
white ash	sprout height in 1985	$y = 3.77x^{0.92}$	56.52	0.0001
trembling aspen	sprout height in 1985	$y = 0.87x + 332$	6.79	0.0525
sugar maple	tree diameter	$y = e^{-0.1x + 6.81}$	20.67	0.0008
sugar maple	sprout height in 1985	$y = 1.99x + 246$	24.43	0.0088

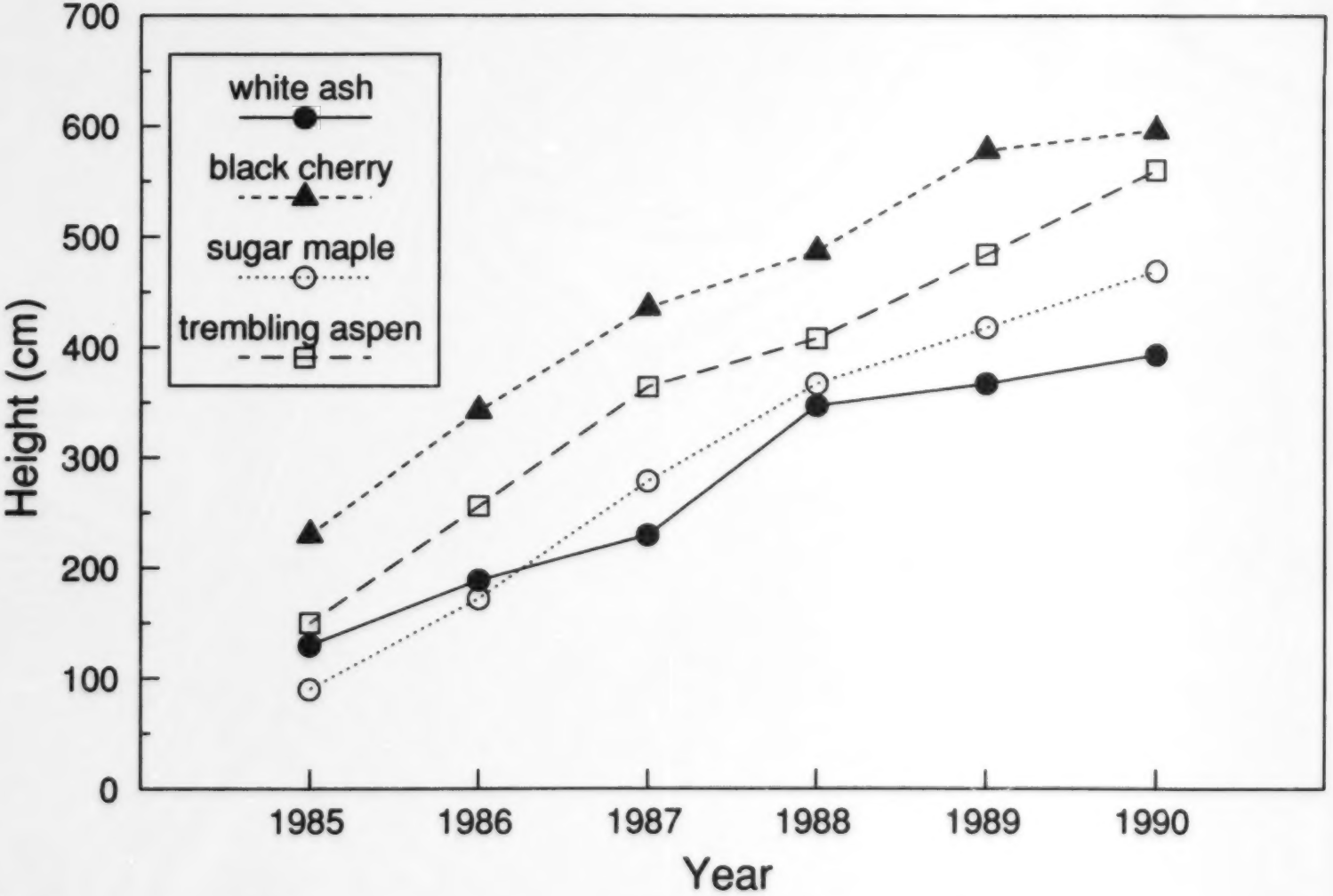

Figure 7: The upper quartile height of the tallest stem on the surviving stumps at McCowan Road

fall of 1986 indicated that there were some tree seeds in the soils (Brown 1988). High seed densities were found for ironwood, dogwood, mulberry, hawthorn and raspberry, although only the raspberry seeds germinated under greenhouse conditions. Mulberry was not found at the site, and the density of dogwood and raspberry have declined since 1986 (Table 1), suggesting that this seed bank had little, if any, input into the tree densities past 1986. This is consistent with literature reports which suggest that most tree and larger shrubs (excluding raspberry) do not maintain a persistent seed bank (Marquis 1975, Schneider and Sharitz 1986). Tree species depend on sprouts and suckers, advance regeneration and the seed rain for recruitment (Livingston and Allesio 1968, Kellman 1974, Marquis 1975, Donelan and Thompson 1980, Vlahos and Bell 1986, Fyles 1989).

The major source of problem stems on a newly constructed right-of-way is the sprouts and suckers (Figure 3). It is apparent from this and other studies (Bramble and Byrnes 1976, Allsbrooks *et al.* 1984, Thibodeau and Nickerson 1986) that the ground cover which develops after the clearing will not adequatly control this growth. Normally, two to three selective herbicide treatments are required to establish a desirable ground cover on a right-of-way (Niering and Goodwin 1974, Bramble and Byrnes 1976). More extensive site preparation, possibly involving grubbing of the stumps and soil scarification, followed by planting of an appropriate cover crop, may be necessary to rapidly establish a high degree of biological control if chemicals are not available for use (Allsbrooks *et al.* 1984).

Sprouts and suckers have occupied the dominant position in the tree canopy throughout this study (Figure 3), and will likely maintain this position for several years. The observed decline in sprout numbers (Figure 5) is the result of a self-thinning process. A stump has only limited area and resources to support sprouts. The initially high sprouting response of black cherry and white ash could not be maintained by the stump, thus these stems exhibited high mortality in the initial stages of the study.

Such rapid declines are common. Lees (1984) reported high initial mortality in red maple (*Acer rubrum*), with sprouts declining from 75 stems·stump^{-1} in the first year following cutting to 30 stems·stump^{-1} after 5 years. Black cherry sprouts have been observed to undergo 50% mortality in the first 2 years, while red maple sprouts underwent a lower, but substantial 30% reduction (Mroz *et al.* 1985). The same study indicated that sugar maple sprouts had better survival during this period, although its initial sprouting response of 25 stems·stump^{-1} was higher than that observed at McCowan Road. The sprouts at McCowan Road are expected to slowly undergo additional reductions to an estimated 3 to 5 stems·stump^{-1} within 20 years (Johnson 1975, Lees 1981).

Several factors have been implicated in the sprouting response. The degree of stump mortality and the initial sprout production may be predicted from the species composition at the site (Figures 4,5), but these predictions cannot be improved upon by including other easily measured parameters of the parent tree (height, diameter or age, Tables 2,3,4). Factors such as the growing conditions (light, moisture and temperature) following cutting, the nutrient reserve in the root system, and the general health of the tree prior to cutting will affect sprouting, but these cannot be manipulated to reduce the response (Schier and Zasada 1973, Blake and Raitanen 1981, Johansson 1986). Additional factors, such as the time of year that the tree is felled, the method of cutting and the height of the stump can be manipulated to minimize the response. Trees cut in the dormant season tend to produce more sprouts than those cut during the growing season (Schier 1973, Arron 1987). Taller stumps also produce more sprouts (Blake and Raitanen 1981, Johansson 1986). The method of clearing may be important. Lees (1984) reported that red maple trees cut with a chainsaw produced fewer sprouts than those mechanically harvested. Rights-of-way clearing machines which tend to shatter or shred the stump would leave a condition considerably different than the clean cut, low stumps left by chainsaws at McCowan Road, thus the sprouting response may be quite different than that documented here.

The life history characteristics of the sprouts and suckers at this site (Figures 5,6,7) may be useful in scheduling the follow up treatments on a newly established right-of-way, but are of limited use for existing

rights-of-ways. The diameter of the stump has a large influence in its initial sprouting response (Brown 1987a). Unfortunately, the initial design of the McCowan Road study was limited to stumps greater than 7 cm in diameter (Kirby 1984), a size which is much larger than that expected on a right-of-way undergoing a regular treatment cycle. The majority of the studies reported in the literature also concentrate on larger trees. Sapling-sized trees have a higher probability of sprouting, although the small stump diameters will only support a few stems (Schier 1978, Powell and Tryon 1979, MacDonald and Powell 1983, Johansson 1986). A transect study at McCowan Road confirmed this (Brown 1987a). Stumps in the 0 to 5 cm diameter class had a higher probability of sprouting, but had fewer and shorter stems on each stump. The recent restrictions to herbicide usage adopted by Ontario Hydro, and the likelihood that these restrictions will be extended in the future, indicate an increased reliance on mechanical methods to remove unwanted species from the right-of-way. As these will be primarily sapling sized trees, additional studies are necessary to fully characterize their sprouting response and determine the most appropriate time of cutting, time between cycles and method of cutting.

5. CONCLUSIONS

1. Sprouts and suckers represent the major source of problem stems on a new right-of-way.

2. Most stump mortality occurs in the first 2 to 3 years. It was species dependant, with sugar maple > white ash > black cherry = trembling aspen. Mortality in white ash may continue for 5 to 6 years.

3. The initial sprouting response cannot be predicted from the age, height or diameter of the parent tree, but is dependent upon species, with white ash = black cherry > trembling aspen > sugar maple. Sprout numbers then decline. All species converge on a mean of 5 to 8 stems·stump^{-1} within 6 years.

4. Growth in height is maximal in the first year, with black cherry > trembling aspen > white ash = sugar maple. Growth rates then decline. By the sixth year the height of black cherry = trembling aspen > sugar maple > white ash.

5. The groundcover which developed following clearing of this site did not adequatly prevent the invasion of tree seedlings or sprouts. If herbicide usage is to be reduced on new rights-of-way, studies are needed to investigate the effect of repeated cutting, grubbing and cover crops on tree establishment.

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